![Duke Energy logo]

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August 18, 2021

VIA ELECTRONIC FILING

The Honorable Jocelyn G. Boyd
Chief Clerk/Executive Director
Public Service Commission of South Carolina
101 Executive Center Drive, Suite 100
Columbia, SC 29210

Re: Petition of Duke Energy Carolinas, LLC and Duke Energy Progress, LLC for Approval of CPRE Queue Number Proposal, Limited Waiver of Generator Interconnection Procedures, and Request for Expedited Review
Docket No. 2018-202-E

Dear Ms. Boyd:

Pursuant to the Public Service Commission of South Carolina's ("Commission") Order No. 2019-247 issued on April 9, 2019, in the above-captioned docket, Duke Energy Carolinas, LLC and Duke Energy Progress, LLC (collectively, the "Companies") hereby respectfully provide the Commission an update on the Companies' most recent Distributed Energy Resources ("DER") Technical Standards Review Group ("TSRG") meeting held on July 21, 2021.

The following attachments enclosed with this update provide a more detailed account of the previous TSRG meeting and issues discussed:

- **Attachment A:** July 21, 2021 Meeting Agenda
- **Attachment B:** July 21, 2021 Minutes and Attendance
- **Attachment C:** Update and Discussion-Action Plan to Implement 1547-2018
- **Attachment D:** Implementation of IEEE 1547-2018 Guidelines (Redline)
- **Attachment E:** Implementation of IEEE 1547-2018 Guidelines (Clean)
- **Attachment F:** DER Commissioning Update
- **Attachment G:** Distributed Energy Technology Operations Role

As described in the Companies' June 6, 2019 Report in this docket, the TSRG webpage, https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg, provides meeting materials from each prior TSRG meeting, as well as other technical standards documents. The next TSRG meeting is tentatively scheduled for October 20, 2021.

Sincerely,

Heather Shirley Smith

Heather Shirley Smith

Attachments

C: Parties of Record (via email w/ attachments)

Interconnection Technical Standards Review Group (TSRG)
Duke Energy Carolinas/Progress
Meeting Agenda
July 21, 2021

In-person meeting converted to web meeting to follow distancing guidelines for COVID-19

9:00	Meeting Administrator remarks
9:02	Safety & Welcome – Wes Davis, Duke
9:05	IEEE 1547 implementation update – Anthony Williams, Duke
9:30	Inspection and commissioning update – Kevin Chen, Duke
10:30	BREAK
10:45	Operations update – Darren Maness, Duke
11:15	Affected systems discussion – Bill/Orvane, Duke
11:30	Roundtable topics
11:45	Queue reform update – Ken Jennings, Duke
11:55	Wrap up & next meeting date – Wes Davis, Duke (Recommend October 20)
12:00	ADJOURN

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

July 21, 2021

I. Opening

This is a regular meeting called to order at 9:00 AM. The meeting was conducted by web conference.

Meeting facilitator: Anthony Williams

Minutes: Anthony Williams

II. Record of Attendance

Member Attendance

Name	Affiliation	Attendance
Anthony Williams	Duke Energy	present
Bill Quaintance	Duke Energy	present
Darren Maness	Duke Energy	present
Huimin Li	Duke Energy	absent
Jonathan DeMay	Duke Energy	present
Kevin Chen	Duke Energy	present
Orvane Piper	Duke Energy	present
Scott Reynolds	Duke Energy	absent
Wes Davis	Duke Energy	present
Adam Foodman	O2 Energies EMC	absent
Ben Brigman	Ecoplexus	present
Brad Micallef	Solar Operations Solutions	present
Bruce Fowler	BAM Energy	absent
Bruce Magruder	BAM Energy	absent
Chris Sandifer	SCSBA	present
Chuck Ladd	Ecoplexus	present
David Brueck	Southern Current	absent
James Wolf	Yes Solar Solutions	absent
Jason Epstein	Southern Current	absent
John Gajda	Strata Solar	present
John Wilson	Southern Current	absent
Luke O'Dea	Cypress	absent
Luke Rogers	Birdseye Renewable Energy	absent
Matt Delafield	R-E Services	absent
Mike Wallace	BrightNight Energy	absent
Mike Whitson	PowerOn Energy	present
Paul Brucke	Brucke Engineering	absent
Scott Griffith	Duke Energy	present
Sean Grier	Duke Energy	absent
Stephen Barkaszi	Duke Energy	present
Dustin Metz	NC Public Staff	absent
James McLawhorn	NC Public Staff	absent

1

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

July 21, 2021

Name	Affiliation	Attendance
Jay Lucas	NC Public Staff	absent
Tommy Williamson	NC Public Staff	absent
Dawn Hipp	SC Office of Regulatory Staff	absent
Morgan O'Neil	SC Office of Regulatory Staff	present
Robert Lawyer	SC Office of Regulatory Staff	absent
Sarah Johnson	SC Office of Regulatory Staff	absent

Guest Attendance

Name	Affiliation	Attendance
Kelsy Green	Advanced Energy for Duke	present
Staci Haggis	Advanced Energy for Duke	present
Ken Jennings	Duke Energy	present

III. Current agenda items and discussion

1) The agenda was emailed prior to the meeting.
2) Wes provided the welcome and safety message

3) PRESENTATION: IEEE 1547 implementation plan – Anthony Williams, Duke
    A) Presentation will be provided with the meeting minutes
    B) Industry question – Does Duke have any plans concerning plant control computers
        (i) Duke response – There is a placeholder section in Guidelines, but for now the main work has been focused on the inverter-based functions and implementation. Duke is aware of plant computers and there are technical areas of concern, but those will be a future consideration.
    C) Duke requested input from the stakeholders on the expected date for 1547-2018 available devices.
        (i) I t was noted that the CEC in CA maintains a list, but it focused on the requirements for Rule 21. Possibly columns would be added for 1547-2018 functions as well
        (ii) https://www.energy.ca.gov/programs-and-topics/programs/solar-equipment-lists
    D) Industry question – When will duke implement the Standard?
        (i) Duke response – As some of the technical, interoperability, and testing requirements are becoming more clear, Duke would like to begin discussions on the time line and number of phases. Possibly, this could be a topic for the October TSRG.
        (ii) Upon preliminary review, the TSRG prioritized topics for 1547 align with those in the industry. That being the case, possibly the Duke implementation can be similar to those beginning to emerge in the industry.

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

July 21, 2021

4) PRESENTATION: Inspection and commissioning update – Kevin Chen, Duke
   A) Presentation will be provided with the meeting minutes
   B) Industry question – What does removing the LV inspection from the scope mean?
      (i) Duke response – The inspection will not check the LV electrical equipment itself. The inverter itself is still within the scope, it is just the inspection will skip the other LV equipment.
   C) Industry question – Will the documentation better define 'major construction' issues?
      (i) Duke response – This varies based on the site, so Duke prefers to clarify this in a separate discussion because this is a detailed question that could best be discussed with site specific issues or examples. Also note that the self-inspection training covers some examples of major issues. Violation of NESC is considered 'major.'
   D) Discussion – Duke noted that scheduling the end of year commissioning worked good last year and would encourage development of a similar schedule again this year.

5) PRESENTATION: Operations update – Darren Maness, Duke
   A) Presentation will be provided with the meeting minutes
   B) Industry question – For early morning issues, like reclosers, show should a DER contact Duke afterhours?
      (i) Duke response – Still contact the DCC. The email address is not monitored 24/7.
   C) Industry question – In early operations, like the time from energization until the PTO, should the DCC still be contacted?
      (i) Duke response – Continue to contact the DCC on these issues once the Duke recloser and meter are operational. If the DCC response is not timely, also contact Darren to facilitate the conversation.

6) Discussion Topic: Affected systems – Bill Quaintance / Orvane Piper, Duke
   A) Discussion – Ken Jennings gave an update on the planned meetings for cost allocation related to affected systems.

7) Discussion Topic: Queue reform update – Ken Jennings, Duke
   A) Discussion – Ken Jennings provided an update of the timeline, process, and status to this point.

8) Roundtable
      (i) Conductor phase identification (phasing) at the interconnection

3

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

July 21, 2021

       (ii) The industry has met with Duke to discuss issues with identifying the phasing at the interconnection. Is there an update?

          (a) Duke response – Duke is working on a process to identify the phasing earlier in the construction process to be prepared for DER interconnection.

          (b) <u>ACTION ITEM – Duke will schedule a follow-up meeting to discuss how conductor phase identification can occur earlier in the process.</u>

9) Wrap up & next meeting date – Wes Davis, Duke

    A) Next meeting is planned to be a web conference.

       (i) Proposed October 20

IV. Closing

This meeting concluded at 11:15 PM

V. Attachments

1) Agenda, "TSRG Agenda 2021_0721, Rev 0.pdf"
2) Presentations

    A) Update and Discussion: Action Plan to Implement 1547-2018, "TSRG Implement 1547 Update, Jul 21 2021, Rev 0.pdf"

    B) DER Commissioning Update, "DER commissioning_TSRG_07212021.pdf"

    C) DET Operations Role, "TSRG Operations Role_07-21-21.pdf"

3) References

    A) 1547 Guidelines with edits, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 4A"

    B) 1547 Guidelines latest version, "Duke Energy IEEE 1547 Implementation Guidelines, Rev 5"

4

Update and Discussion: Action Plan to Implement 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

DER Technical Standards
July 21, 2021

DUKE ENERGY

- Review main revisions
  - Current version is "Duke Energy IEEE 1547 Implementation Guidelines, Rev 5"
    - Rev 4A is the redline version of Rev 5
- Discussion

Attachment C

Comparison with NE-ISO and HI Requirements

- Verified the Duke Guidelines were congruent and adjusted guidelines as necessary
    - Still, these are only a few of the many requirements
- Assigned 8.1 Unintentional islanding to Priority Group 2
    - Duke plans to accept the requirements in the Standard as written
- Miscellaneous changes in
    - Section 5.3 – Voltage and reactive power control
    - Section 6.5.2 – Frequency disturbance ride-through requirements

Attachment C

Volt-VAR "After study" Conclusions

First study assumption

- Time series identifies the worst case load and generation scenarios
    - Max voltage at PCC is not always minimum load, but typically is: 12/15 — At min load
    - Max dV/dP is always at maximum load — At min load
    - Min dV/dQ is always minimum load — At min load
- Highest PCC voltage is at maximum Pgen for most feeders: 11/15 — At max Pgen
    - A few in the 50 – 70% Pgen range (when gen / peak load > 2)
- dV/dQ is constant — Constant
- dV/dP much more likely to have significant variation — Constant
    - Vary across system conditions
    - Sensitivity may change sign; concave PCC voltage as gen / peak load > 2
- Characterizing the feeder by the response factors can be useful in assessing the effectiveness of reactive power control at the DER — Useful
- While impedance is an important characteristic, stiffness continues to not correlate well — Don't use stiffness

Attachment C

Stakeholder thoughts about equipment availability

- Discuss implementation schedule and timeline later this year
    - Stakeholder expectations of when IEEE 1547 certified devices will be available / when are projects expected to start using UL 1741 SB inverters?

Attachment C

Previously Completed Sections

- DUK-13 Section 4.5 – Cease to energize performance requirement
- DUK-27 Section 4.7 – Prioritization Of DER Responses
- DUK-28 Section 4.8 – Isolation device
- DUK-23 Section 4.9 – Inadvertent energization of the Area EPS
- DUK-29 Section 4.11.1 – Protection from electromagnetic interference
- DUK-30 Section 4.11.2 – Surge withstand performance
- DUK-22 Section 4.11.3 – Paralleling device
- DUK-26 Section 4.12 – Integration with Area EPS grounding, ready to be implemented
- DUK-01 Section 5.2 – Reactive power capability of the DER
- DUK-05 Section 7.2.3 – Flicker
- DUK-05 Section 7.3 – Limitation Of Current Distortion

Attachment C

- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide both comments and also propose a specific change:

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Suggesting the exact change to the Guidelines reinforces the main point of the comment and provides more information that Duke can specifically address
- Comments will be taken during the meeting and the form will be distributed after the meeting
- Stakeholders may provide written feedback using the feedback form by emailing to: DER-TechnicalStandards@duke-energy.com

Attachment C

Attachment C

8

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 4

April 28, 2021

**Implementation of IEEE 1547-2018 Guidelines for
Duke Energy Carolinas and Duke Energy Progress**

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to July 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	General update prior to Jan. 2021 TSRG meeting
4	4/28/2021	General update prior to Apr. 2021 TSRG meeting

CONTENTS

Attachment D

1

INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

> Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

- i) 4.6.2 Capability to limit active power
- ii) 5.3 Voltage and reactive power control
- iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS AND REQUIREMENTS

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

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[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy IEEE 1547-2018 Guidelines

1

2   Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
2 (DUK-103)	8.1	Unintentional islanding	TBD	Yes	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	~~TBD,~~ Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	~~TBD,~~ Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	~~TBD,~~ Eval + Comm Test
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	No Reqmt	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test

Duke Energy IEEE 1547 Implementation Guidelines, Rev 4A.docx ~~Duke Energy IEEE 1547 Implementation Guidelines, Rev 4.docx~~

5

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-
~~(DUK-103)~~	~~8.1~~	~~Unintentional islanding~~	~~TBD~~	~~Yes~~	~~-~~
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-

Duke Energy IEEE 1547 Implementation Guidelines, Rev 4A.docx ~~Duke Energy IEEE 1547 Implementation Guidelines, Rev 4.docx~~

6

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

1

LOGISTICS OF IMPLEMENTING OF IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the
necessary changes to implement that section. This could vary from taking no action, to updating
documentation, to changing work, study, and operational practices. Additionally, a consequence of more
inverter functions will be the necessary increase in interoperability requirements as well as DER equipment
and DER system verification and testing to confirm design and functional requirements. There are many
aspects to consider before implementing each 1547 section. Because the actions to implement each
section can vary widely, the implementation will be addressed in each section rather than as a whole for
the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are
tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-
2018 certified. All functions and requirements may not be applicable or implemented at the time the
inverters become certified or that Duke Energy requires the certification.

Duke Energy has no plans to implement the new functions of IEEE 1547-2018 for existing inverters. Not only
is it not a common practice at Duke to retroactively apply standards, it is really not even a valid option
because existing inverters do not have many of the 1547-2018 capabilities and were not tested to
UL 1741 SB. If a 1547-2018 function is implemented and there is a comparable IEEE 1547a-2014 function
for inverters certified to UL 1741 SA, then Duke Energy and the DER Owner may mutually agree to
implement those available functions as needed. Similarly, some functions like voltage and frequency
tripping have existed throughout all versions of 1547. Revising pre-existing settings is not considered
implementation of a new function.

1 PLANT REQUIREMENTS

2 Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant
3 controller rather than at the individual inverter units. There may need to be some tests for verification that
4 the plant controller performs the intended functions and that the underlying inverters to not behave
5 contrary to the plant controller configuration or commands.

6

7

8 Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or
9 subsection number and title.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

11 Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of
12 common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the
13 local EPS or DER EPS.

14 The technical specifications and requirements for some performance categories are specified by general
15 technology-neutral categories. For categories related to reactive power capability and voltage regulation
16 performance requirements, Duke Energy requires the following normal performance category:

17   Voltage and Reactive Power Category B

18 For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following
19 abnormal operating performance categories:

20   Synchronous generation   Category I
21   Induction generation   Mutual agreement
22   Inverter-based generation   Category III*
23   Inverter-based storage   Category III*

24 This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual
25 agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or
26 UL 1741 SA.

27 * Final determination for the Category has not been made. More analysis is required and included as part of
28 a study conducted jointly between the Duke Protection and Transmission Planning groups. This work
29 includes a significant effort to model the system, perform iterative studies, and perform research. The
30 main focus is on Category II and that is expected to be the minimum requirement for IBR. With the
31 amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most
32 likely selection.

33 Interoperability requirements: No specific requirements for this section.

34 Verification and test requirements: Independent laboratory certifications that attest to the normal and
35 abnormal categories shall satisfy verification for this requirement.

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8

1 Implementation of this section requires publishing the final position and integrating verification
2 requirements into the overall commissioning test program.

3

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

6 Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common
7 coupling), which is also known as the point of delivery or change of ownership point on the medium voltage
8 side of the DER transformer(s). The RPA for net meter installations is the PoC (point of connection) at the
9 inverter terminals.

10 See informative Annex H, in the Standard and the decision tree in IEEE 1547.2.

11 Duke may choose to also reference Figure 3, "Use of Power Limiting in the RPA Selection Process" from the
12 final 1547.2 Standard once the standard is published. This figure contains a flow chart that may be more
13 concise than those in Annex H.

14

15 Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still
16 determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

17

Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:

   a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*

   b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

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9

1 The final position must consider the variety of RDER and UDER interconnections and identify the RPA for
2 each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. Zero
3 sequence continuity is not a factor for UDER, so the RPA for UDER is the PCC (point of common coupling at
4 the utility interconnection point).   The RPA for net meter installations must consider a variety of
5 conditions, as noted in the decision trees, H.1 and H.2.   Note that Section 4.12 also addresses grounding
6 and zero sequence continuity.

7 Interoperability requirements: No specific requirements for this section.

8 Verification and test requirements: Duke will to review DER design documents to confirm the location of
9 the RPA is correct.

10 Implementation of this section requires publishing the final technical position.

11

SECTION 4.3 – APPLICABLE VOLTAGES

13 Duke Energy will consider if there is a need to clarify any technical points for the final version of the
14 guideline, but the expectation is that the section is implemented as written. The expected outcome is that
15 RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at
16 the EPS voltage level and used for inverter functions.

17 Duke accepts the requirements in the Standard as written.

18 Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke
19 Energy.

20 Verification and test requirements: To be determined.

21 The applicable voltage should be identified in the interconnection process. Duke plans to review design
22 document to verify the DER meet this requirement.

23 Implementation of this section requires ~~publishing the final position,~~ applying the interoperability
24 functionality in the local interface, and integrating verification requirements into the overall commissioning
25 test program.

26

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

29 Duke Energy requires cease to energize capability (not delivering power during steady-state or transient
30 conditions) in accordance with the Standard.

31 A DER can be directed to cease to energize and trip by changing the Permit service setting to "disabled" as
32 described in IEEE 1547 subsection 4.10.3.

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10

1   Interoperability requirements: No specific requirements for this section.

2   Verification and test requirements: Duke plans to review design document and equipment specification to
3   identify the interconnection device that provides the cease-to-energize function. The existing inspection
4   and commissioning process tests to verify the device meets the performance requirement.

5   This section is ready to be implemented.

6

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

8   Duke Energy will consider if there is a need to clarify any technical points for the final version of the
9   guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

10   Duke accepts the ~~capabilities~~ requirements in the following Standard sections as written:
11   4.6.1 Capability to disable permit service
12   4.6.2 Capability to limit active power
13   4.6.3 Execution of mode or parameter changes

14   This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication
15   interface.

16   4.6.1 Capability to disable permit service

17   For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting
18   at the local EPS.

19   Application to RDER has not been assessed.

20   Interoperability requirements: The present automation controller implementation includes a disable
21   permit service control. The automation controller has the capability to provide a limit active power Analog
22   Output sent via SCADA to control active power.

23   Verification and test requirements: Duke will review UL certification tests, type tests, design documents,
24   and equipment specifications to identify the capability of the DER to meet this performance requirement.
25   Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the
26   permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW,
27   Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case,
28   the permit service is implemented at the DER unit through the small DG interface.

29

30   4.6.2 Capability to limit active power

31   Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum
32   active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is
33   not possible without upgrades. The Standard defines the active power limit as a percentage of the
34   Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power

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11

1 Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not
2 have the capabilities to adjust the limit based on time of day, load, or other variables.

3 Duke does not plan to implement real-time control during the initial implementation of the Standard.
4 Significant technical studies are required to address concerns and consider remote real-time control of the
5 active power limit. However, it is reasonable to make provision for this potential capability when designing
6 the monitoring and control capabilities of the communication interface.

7 ~~Interoperability requirements: The present automation controller implementation Analog Output sent via~~
8 ~~SCADA to control active power.~~

9 ~~Verification and test requirements: Duke will review UL certification tests, type tests, design documents,~~
10 ~~and equipment specifications to identify the capability of the DER to meet this performance requirement.~~
11 ~~Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the~~
12 ~~permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW,~~
13 ~~Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case,~~
14 ~~the permit service is implemented at the DER unit through the small DG interface.~~

15 Implementation of this section requires publishing the final technical position.

16

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

18 Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this
19 section of the Standard.

20 Interoperability requirements: No specific requirements for this section.

21 Verification and test requirements: Duke plans to review UL certification testing, type tests results, and
22 design documents to evaluate if a DER can meet this requirement.

23 This section is ready to be implemented.

SECTION 4.8 – ISOLATION DEVICE

25 Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines,
26 and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

27 Interoperability requirements: No specific requirements for this section.

28 Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this
29 requirement.

30 This section is ready to be implemented.

31

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12

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

> 4.10.2 Enter service criteria
> 4.10.3 Performance during entering service
> 4.10.4 Synchronization

Section 6.6 of the Standard is also encompassed by the requirements of Section 4.10.

Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER rather than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

When entering service, the DER shall not energize the Area EPS until the following conditions are met at the RPA:

Enter service value	Parameter Label	RDER sSetting (Service tx sec)
Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.1 p.u.

> Note: The parameter labels are based on the publicly available EPRI technical update document number 3002020201, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020.*"Common File Format for Distributed Energy Resources Settings Exchange and Storage."*

1 The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through
2 settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the
3 same Standard default values.

4

5 The DER shall not enter or return to service or ramp faster than the times stated below. A randomized time
6 delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing
7 active power steps greater than 20% of Nameplate Active Power rating shall require approval during the
8 system interconnection study process.

Time Delay	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

9

10 While the active power is ramping during the enter service period, the reactive power shall follow the
11 configured mode and settings.

12 When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is
13 dependent on the Configuration Active Power Rating per the table below:

Rate of Change Duration	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
ESS ≤ 1 MW	None	2	n/a
ESS > 1 MW	None	n/a	ESS MW range / (2 MW/sec)

14

15 The ESS MW range is the sum of the charge and discharge capability.

16 Interoperability requirements: No specific requirements for this section.

17 ~~Interoperability requirements: o be determined.~~

18 Duke will evaluate if there is value in monitoring the enter service settings.

19 Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return
20 to service settings in the field. The existing inspection and commissioning process tests to verify DER meets
21 this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents
22 to evaluate DER's synchronization capability meeting this requirement. The on-off test during
23 commissioning will field verify DER's synchronization capability.

24 Implementation of this section requires publishing the final technical position and applying the
25 interoperability functionality in the local interface.

26

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14

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke Energy requires the DER to meet the requirements of all the following subsections:

> 4.11.1 Protection from electromagnetic interference
> 4.11.2 Surge withstand performance
> 4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. The Standard adopted "44%" as the injection capability for 0.90 pf, but the percentage is actually slightly less, 43.6%. Duke will consider capabilities 43.6% and higher also meet the intent of the 44% requirement. As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability shall be provided on an inverter capability curve (P-Q graph) and shall be based at the rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).

Because operating points on the chart can be difficult to accurately determine, it is recommended that the DER provide the numerical data that defines critical points on the capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of a facility capability curve that includes any limitations.

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may elect to submit data at a higher ambient temperature. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified.

---

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

1 Additionally, if there are multiple devices that form the complete DER, a composite capability curve that
2 includes all sources, loads, and supplemental devices shall be provided.

3

4 Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be
5 specified and Duke recommends submittal of a facility capability curve that includes the limitations.

6 Interoperability requirements: No specific requirements for this section.

7 Verification and test requirements: Duke plans to evaluate design documents and equipment specifications
8 to determine reactive power capability. A field test may be required for DER to prove its reactive power
9 capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

10 ~~Implementation of this section requires publishing the final position and integrating verification~~
11 ~~requirements into the overall commissioning test program.~~

12 This section is ready to be implemented.

13

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

15 Listed below are the Standard voltage and reactive power control options and the default status for Duke
16 interconnections:~~The Standard lists several forms of reactive power control:~~

Control Mode	Default Status
Constant power factor (fixed pf)	On, 1.0 pf
Constant reactive power (fixed VAR)	Off
Voltage-reactive power (Volt-VAR)	Off
Active power-reactive power (Watt-VAR)	Off

17

18 Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is
19 the broad category of control that includes unity power factor, which can be useful, but is limited by
20 operating at a control point that is not based on feeder conditions. Duke is in the process of performing
21 studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER.
22 The Duke study will evaluate the application and consequences of these functions.

23 Part of the study effort is to determine if voltage regulation functions should be activated and how they
24 should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the
25 system impacts, identify any unanticipated effects, and then assess the control modes and settings.
26 Because the impact of UDER reactive injection can be large, Duke limits the reactive capability that can be
27 used for reactive power control to 0.95 power factor.

28 In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed.
29 Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration
30 for residential-scale inverters as well. The reactive control method and settings should consider existing
31 operational requirements as well as mitigation of the high voltages that can occur with the addition of DER.

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17

1 No change can be made on one part of the system that does not affect another part. Therefore, the study
2 will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts,
3 remediation of impacts, and controlling the impact on the transmission system. Distribution Providers
4 must comply with agreements and requirements of the transmission entities. As such, an evaluation of
5 transmission impacts is important.

6 Significant technical studies are required to evaluate these functions and analyze the consequences. The
7 studies began at the end of 2019 and will continue in 2021. This will continue to be an agenda item for the
8 TSRG meetings will focus on the most useful control modes and settings that are applied locally in the
9 inverter and are autonomous.

10 Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision.

11 Interoperability requirements: To be determined.There will be few, if any, requirements for fixed power
12 factor DER. For other control modes, the interoperability requirements align with those in the EPRI
13 document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI,
14 Palo Alto, CA: 2020. 3002020201.

15

16 Even with autonomous operation there will be some requirements to communicate the VAR priority mode
17 and reactive power mode to Duke, and possibly other information. Because those requirements are not
18 known at this time, Duke must perform additional analysis and interface testing for autonomous operation.
19 For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the
20 future, there may be value in providing the necessary controls for remote utility control. That is second
21 priority to autonomous operation, but that would require even more controls and monitoring. While
22 priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the
23 individual control setpoints for each mode.

24 At this time, Duke does not have the capability to remotely control or manage distribution connected
25 reactive power resources. However, there is some expectation that functionality may be necessary or
26 available within the life of the DER. Facilities may want to make provision for interoperability capabilities
27 that include both autonomous operation as well as remote control and adjustment of setpoints.

28 Verification and test requirements: To verify DER compliance to this requirement, Duke will require
29 evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage
30 tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may
31 be required to evaluate the DER's performance meeting this requirement.

32 Additional analysis must be performed before finalizing the Verification and test requirements.

33 Implementation of this section requires publishing the final position, applying the interoperability
34 functionality in the local interface, and integrating verification requirements into the overall commissioning
35 test program.

36

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined. The interoperability requirements align with those in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to

1 optimize protection and ride-through performance and establish the abnormal operating performance
2 Categories.

3 Interoperability requirements: No specific requirements for this section.To be determined.

4 Duke Energy must evaluate if there are any interoperability requirements for this section.

5 Verification and test requirements: The existing inspection and commissioning process covers the
6 verification of this requirement. Duke plans to continue the practice and refine the process as necessary
7 following the commissioning test requirements in IEEE 1547.1.

8 Implementation of this section requires publishing the final position, applying the interoperability
9 functionality in the local interface.

10

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

12 Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as
13 written, there may need to be clarifications.

14 This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is
15 an enormous effort to model the system, perform iterative studies, perform the research, and evaluate
16 protection settings. Duke Energy is working to determine the best DER recloser protection elements to
17 optimize protection and ride-through performance and establish the abnormal operating performance
18 Categories.

19 Interoperability requirements: No specific requirements for this section.

20 Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such
21 coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will
22 follow the commissioning tests requirements in IEEE 1547.1.

23 Implementation of this section requires publishing the final position.

24

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

27 Duke Energy has not determined the guidelines for this section.

28 This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is
29 an enormous effort to model the system, perform iterative studies, perform the research, and evaluate
30 protection settings. Duke Energy is working to determine the best DER recloser protection elements to
31 optimize protection and ride-through performance and establish the abnormal operating performance
32 Categories. As placeholders, the present trip setpoints are added to the Guidelines.

1   Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and

2   frequency settings and time delays that provide adequate ride-through for BES events. The team is still

3   reviewing the impact to system protection with the proposed settings.

4

1 For new DER installations, the present voltage tripping setpoints are provided in the table below.

Parameter	Voltage	Time
Undervoltage, UV Level 1	0.88 pu	10 cycles
Undervoltage, UV Level 2	0.5 pu	6 cycles
Overvoltage, OV Level 1	1.1 pu	10 cycles
Overvoltage, OV Level 2	1.2 pu	6 cycles

2

3 Interoperability requirements: To be determined.

4 It is expected that these values will be set and not changed remotely, however this position must be
5 evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be
6 a beneficial capability. Because requirements are not known at this time, Duke must perform additional
7 analysis before establishing interoperability requirements. Note that this setting is incorporated in
8 SUNSPEC MODBUS.

9 Verification and test requirements: The existing inspection and commissioning process covers the voltage
10 trip settings field verification and Duke plans to continue that practice. Due to complication of performing
11 abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for
12 the purpose of evaluating conformance of the DER, and currently does not plan to require field
13 commissioning tests on this topic. Operational data collection after a DER or system event may be required
14 to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be
15 considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made
16 if verification of the mandatory trip function is required.

17 Implementation of this section requires publishing the final position and applying the interoperability
18 functionality in the local interface.

19

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

22 Duke Energy has not determined the guidelines for this section, but these requirements are being
23 developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

24 See Section 1.4 for the abnormal performance category.

25 Interoperability requirements: To be determined.

26 It is expected that these values will be set and not changed remotely, however this position must be
27 evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be
28 a beneficial capability. Because requirements are not known at this time, Duke must perform additional

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22

analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements. As placeholders, the present trip setpoints are added to the Guidelines.

For new DER installations, the present frequency tripping setpoints are provided in the table below.

Parameter	Frequency	Time
Underfrequency, UF	57 Hz	10 cycles
Overfrequency, OF	60.8 Hz	10 cycles

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

1 Verification and test requirements: The existing inspection and commissioning process covers the
2 frequency trip settings field verification and Duke plans to continue that practice. Due to complication of
3 performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation
4 evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require
5 field commissioning tests on this topic. Operational data collection after a DER or system event may be
6 required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be
7 considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made
8 if verification of the mandatory trip function is required.

9 Implementation of this section requires publishing the final position and applying the interoperability
10 functionality in the local interface.

11

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

14 For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

15 Duke Energy has not determined the guidelines for this section, but these requirements are being
16 developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

17 The Standard also includes several subsections related to frequency. Although Duke Energy considers these
18 requirements mainly as functional specifications for the inverter, Duke Energy does have additional
19 requirements or clarifications.

20 6.5.2.5 Rate of change of frequency (ROCOF)
21 UL certification testing should verify the inverter will ride through a 3 Hz/s excursion in accordance with
22 abnormal operating performance Category III. That being the case, no generator on the utility system shall
23 intentionally trip for ROCOF using protective relaying or DER controller functions. DER tripping for ROCOF, if
24 available, should be off or disabled. The DER shall certify that protective relay settings & controller settings
25 do not intentionally trip for ROCOF.

26 This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates
27 adopting the 1547 requirements if that is supported by the ongoing project.

28 6.5.2.6 Voltage phase angle changes ride-through
29 The UL 1741 SB certification shall be considered sufficient for individual inverter based DER devices meeting
30 ride through requirements for this function. The DER shall certify that protective relay settings & controller
31 settings of the completed DER facility do not intentionally trip for the voltage phase angle changes specified
32 by the Standard.

33

34 This function, either at the inverter or the utility PCC recloser, is still under evaluation as part of an ongoing
35 project involving the Protection and Transmission Planning groups. Duke anticipates adopting the 1547
36 requirements above if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

Duke accepts the default operation conditions and settings in the Standard as written:

Operation for low-frequency conditions	Mandatory
Operation for high-frequency conditions	Mandatory

Parameter	Setting
dbOF, dbUF (Hz)	0.036
kOF, kUF	0.05
T-response (small-signal) (s)	5

At this time, a frequency deadband of 36 mHz and a droop of 5% are considered acceptable for inverter and non-inverter sources. As the mix of generation sources transition over time, it may be necessary to transition to a lower values in the future to maintain EPS reliability.

This function is still under evaluation as part of an ongoing project involving the Protection and Transmission Planning groups.. Per Standard table 24, a specification of the droop, deadband, and associated parameters is required for Category II and III.

6.5.2.8 Inertial response

Duke Energy has not determined the guidelines for this subsection. This capability is not required by the Standard but is permitted.

Interoperability requirements: To be determined.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required. Also note for the individual functions, that Duke reserves the right to verify that protective relay settings & controller settings do not interfere with or prevent proper performance the various ride-through requirements.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

> Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.
>
> Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the inrush mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test).Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

SECTION 7.2.3 – FLICKER

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

1 Interoperability requirements: No specific requirements for this section. Installation of a power quality
2 meter is already part of the required design for DER 1 MW and greater.

3 Verification and test requirements: Duke plans to follow the commissioning tests requirements in
4 IEEE 1547.1.

5 This section is ready to be implemented.

6

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

9 Duke Energy adopts these requirements as written in the Standard.

10 Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the
11 interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be
12 verified by UL certification testing. However, the DER facility must still be analyzed during system impact
13 study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The
14 limits defined in parts a) and b) must be verified by power system study.

15 Interoperability requirements: No specific requirements for this section.

16 Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results,
17 and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to
18 develop a test procedure and criteria for transient overvoltage during the commissioning test. A power
19 quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in
20 IEEE 1547.1.

21 This section is ready to be implemented.

22

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

25 Duke Energy has not determined the guidelines for this section. More industry experience or analysis could
26 be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised
27 and UL 1741 certification tests include this verification. At that time, Duke expects to adopt these
28 requirements as written in the Standard.

29 Interoperability requirements: No specific requirements for this section.

30 Verification and test requirements: Duke plans to review type tests results and design documents to
31 evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and
32 criteria for transient overvoltage during the commissioning test. A power quality meter is required for the
33 field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

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27

Implementation of this section requires publishing the final technical position.

SECTION 8.1 – UNINTENTIONAL ISLANDING

> Duke Energy has not determined the guidelines for this section.
>
> This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. As placeholders, the expected requirement is noted below.

Duke accepts the requirements in the following Standard sections as written:

      8.1.1 General

      8.1.2 Conditional extended clearing time

      8.1.3 Area EPS with automatic reclosing

The standard clearing time for an unintentional island is 2 seconds. The DER shall identify and provide the method of islanding detection* used for all DERs above 250 kW.

Interoperability requirements: No control points are expected. Need to determine if any monitoring is necessary.

Verification and test requirements: Duke plans adopt the unintentional islanding test procedure in IEEE 1547.1-2020. For a DER that has autonomous capabilities to detect unintentional islands, the cease-to-energize function test as defined in the existing inspection and commissioning process shall be used to verify compliance.

* Such as one of the six groups listed in section 2.3 Generic Island Detection Groups and Response Models of Inverter-Onboard Islanding Detection Assessment: Final Project Report. EPRI, Palo Alto, CA:2020. 3002014051.

SECTION 10.3, 10.4 – NAMEPLATE AND CONFIGURATION INFORMATION

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating

Configuration Apparent Power Maximum Rating

Nameplate Active Power Rating (unity power factor)

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28

1   Configuration Active Power Rating (unity power factor)

2

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3   The list above does not address all the terms in the table. Such a specification is not necessary of every
4   term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently,
5   operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not
6   applicable to abnormal or protection settings).

---

7   Ratings are considered a permanent characteristic of a device or a system and are characterized by:

8   • Rating is the full capacity of the equipment or system.
9   o The rating is the <u>most</u> capacity the system is <u>designed</u> to provide
10   • Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long
11   periods without exceeding design limits and without reducing the life or maintenance interval.
12   o Also, there can be short-term ratings that are time limited. Operation within the
13   parameter and time limit does not exceed design limits or negligibly reduce the life or
14   maintenance interval.
15   • Rating is the base upon which other model, analysis, and inverter parameters are referenced.
16   • Ratings are a common way to identify and classify devices.

17   Limits are not included in these sections of the Standard. However, their relationship to and differences
18   from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than
19   or equal to ratings. Limits are characterized by:

20   • Limits impose boundaries on device operation, often to restrict operation within ratings.
21   • Limits can be established or defined by contractual, system design, or physical equipment
22   restrictions.
23   • Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
24   • Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

25   The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important
26   base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some
27   equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or
28   Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not
29   acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower
30   rating. While the minimum of these two values sets the overall rating, it can be important to distinguish
31   between these when it comes to equipment specifications and modeling.

UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

32

33   The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the
34   completion of the higher priority topics. Concerning the clauses and sections not addressed in this
35   document, Duke Energy expects that the DER shall conform to the Standard itself as written.

36

37

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1 APPENDIX – IEEE 1547-2018 BENCHMARKING

2 Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January
3 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant
4 Consulting, Inc.

5 **TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION**

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

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IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

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Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 5

July 20, 2021

**Implementation of IEEE 1547-2018 Guidelines for
Duke Energy Carolinas and Duke Energy Progress**

Revision	Date	Description
0	3/31/2020	Initial issue
1	7/21/2020	General update prior to Jul. 2020 TSRG meeting
2	10/28/2020	General update prior to Oct. 2020 TSRG meeting
3	1/20/2021	General update prior to Jan. 2021 TSRG meeting
4	4/28/2021	General update prior to Apr. 2021 TSRG meeting
5	7/20/2021	General update prior to Jul. 2021 TSRG meeting

CONTENTS

1

INTRODUCTION

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

> Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

CONSIDERATION OF IEEE 1547 SECTIONS THAT COULD INCREASE INTERCONNECTION CAPABILITY

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

    i)   4.6.2 Capability to limit active power
    ii)   5.3 Voltage and reactive power control
    iii)   5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

CONSIDERATION OF IEEE 1547 SECTIONS THAT IMPACT GRID SUPPORT

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

1 PRIORITY OF IMPLEMENTING THE IEEE 1547 TECHNICAL SPECIFICATIONS
2 AND REQUIREMENTS

3 There are many aspects of implementing the Standard that must be considered. The technical specifications
4 and requirements must be understood and assessed to determine if there is a need to clarify any technical
5 points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders,
6 NC Public Staff, and industry documents were included in the activity to set priority for the various
7 Standard sections. The areas of the Standard that stand out as most important are the ride through
8 capability and voltage and reactive power controls.

9 Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list,
10 then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke
11 identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses
12 and sections that do not have a priority assigned will be undertaken following the completion of the higher
13 priority topics. The three columns on the far right side of the table summarize the status for the technical,
14 interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not
15 the final decision because the topic requires more analysis and assessment. However, this table still
16 provides a general overview.

17

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[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy IEEE 1547-2018 Guidelines

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2 Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
2 (DUK-103)	8.1	Unintentional islanding	TBD	Yes	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	Eval + Comm Test
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	No Reqmt	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

LOGISTICS OF IMPLEMENTING OF IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification.

Duke Energy has no plans to implement the new functions of IEEE 1547-2018 for existing inverters. Not only is it not a common practice at Duke to retroactively apply standards, it is really not even a valid option because existing inverters do not have many of the 1547-2018 capabilities and were not tested to UL 1741 SB. If a 1547-2018 function is implemented and there is a comparable IEEE 1547a-2014 function for inverters certified to UL 1741 SA, then Duke Energy and the DER Owner may mutually agree to implement those available functions as needed. Similarly, some functions like voltage and frequency tripping have existed throughout all versions of 1547. Revising pre-existing settings is not considered implementation of a new function.

PLANT REQUIREMENTS

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that

the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

SECTION 1.4 – GENERAL REMARKS AND LIMITATIONS

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

> Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

SECTION 4.2 – REFERENCE POINTS OF APPLICABILITY (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling), which is also known as the point of delivery or change of ownership point on the medium voltage side of the DER transformer(s). The RPA for net meter installations is the PoC (point of connection) at the inverter terminals.

See informative Annex H, in the Standard and the decision tree in IEEE 1547.2.

Duke may choose to also reference Figure 3, "Use of Power Limiting in the RPA Selection Process" from the final 1547.2 Standard once the standard is published. This figure contains a flow chart that may be more concise than those in Annex H.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:

    a)   Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*

    b)   Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. Zero sequence continuity is not a factor for UDER, so the RPA for UDER is the PCC (point of common coupling at the utility interconnection point).   The RPA for net meter installations must consider a variety of

conditions, as noted in the decision trees, H.1 and H.2.   Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will to review DER design documents to confirm the location of the RPA is correct.

Implementation of this section requires publishing the final technical position.

SECTION 4.3 – APPLICABLE VOLTAGES

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Duke accepts the requirements in the Standard as written.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 4.5 – CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to "disabled" as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

1   This section is ready to be implemented.

2

SECTION 4.6 – CONTROL CAPABILITY REQUIREMENTS

4   Duke Energy will consider if there is a need to clarify any technical points for the final version of the
5   guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

6   Duke accepts the requirements in the following Standard sections as written:
7   4.6.1 Capability to disable permit service
8   4.6.2 Capability to limit active power
9   4.6.3 Execution of mode or parameter changes

10   This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication
11   interface.

12   4.6.1 Capability to disable permit service

13   For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting
14   at the local EPS.

15   Application to RDER has not been assessed.

16   Interoperability requirements: The present automation controller implementation includes a disable
17   permit service control. The automation controller has the capability to provide a limit active power Analog
18   Output sent via SCADA to control active power.

19   Verification and test requirements: Duke will review UL certification tests, type tests, design documents,
20   and equipment specifications to identify the capability of the DER to meet this performance requirement.
21   Duke's current policy requires a utility owned interconnection recloser for UDER >= 1MW. In this case the
22   permit service is implemented by controlling the utility owned recloser. For DER >= 250kW and <1MW,
23   Duke allows the option of installing the small DG interface instead of the utility owned recloser. In this case,
24   the permit service is implemented at the DER unit through the small DG interface.

25

26   4.6.2 Capability to limit active powerNote that 4.6.2 is essentially part of the system impact study (SIS)
27   process now because the maximum active power capacity (import or export) is often calculated during the
28   SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power
29   limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the
30   Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually
31   set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other
32   variables.

33   Duke does not plan to implement real-time control during the initial implementation of the Standard.
34   Significant technical studies are required to address concerns and consider remote real-time control of the

active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Implementation of this section requires publishing the final technical position.

SECTION 4.7 – PRIORITIZATION OF DER RESPONSES

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review UL certification testing, type tests results, and design documents to evaluate if a DER can meet this requirement.

This section is ready to be implemented.

SECTION 4.8 – ISOLATION DEVICE

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

SECTION 4.9 – INADVERTENT ENERGIZATION OF THE AREA EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

SECTION 4.10 – ENTER SERVICE

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.10.2 Enter service criteria

4.10.3 Performance during entering service

4.10.4 Synchronization

Section 6.6 of the Standard is also encompassed by the requirements of Section 4.10.

When entering service, the DER shall not energize the Area EPS until the following conditions are met at the RPA:

Enter service value	Parameter Label	Setting
Minimum Voltage	ES_V_LOW	≥ 0.917 p.u.
Maximum Voltage	ES_V_HIGH	≤ 1.05 p.u.
Minimum Frequency	ES_F_LOW	≥ 59.5 p.u.
Maximum Frequency	ES_F_HIGH	≤ 60.1 p.u.

Note: The parameter labels are based on the publicly available EPRI technical update document number 3002020201, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020.

The final UDER settings are still under evaluation. Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The DER shall not enter or return to service or ramp faster than the times stated below. A randomized time delay is optional and not currently used within the Duke system. As noted in the standard, DER increasing active power steps greater than 20% of Nameplate Active Power rating shall require approval during the system interconnection study process.

Time Delay	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
Enter Service Delay	ES_DELAY	300	300
Enter Service Ramp Period	ES_RAMP_RATE	300	300
Enter service randomized delay	ES_RANDOMIZED_DELAY	Off	Off

While the active power is ramping during the enter service period, the reactive power shall follow the configured mode and settings.

When connected in parallel with the Area EPS, energy storage DER (ESS) active power rate of change is dependent on the Configuration Active Power Rating per the table below:

Rate of Change Duration	Parameter Label	RDER setting (seconds)	UDER setting (seconds)
ESS ≤ 1 MW	None	2	n/a
ESS > 1 MW	None	n/a	ESS MW range / (2 MW/sec)

The ESS MW range is the sum of the charge and discharge capability.

Interoperability requirements: No specific requirements for this section.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement. For 4.10.4, Duke plans to review UL certification tests, type tests, and design documents to evaluate DER's synchronization capability meeting this requirement. The on-off test during commissioning will field verify DER's synchronization capability.

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

SECTION 4.11 – INTERCONNECT INTEGRITY

Duke Energy requires the DER to meet the requirements of all the following subsections:

      4.11.1 Protection from electromagnetic interference
      4.11.2 Surge withstand performance
      4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

SECTION 4.12 – INTEGRATION WITH AREA EPS GROUNDING

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below. Therefore, configurations that are not listed are not approved. It is possible for an IC to submit another winding configuration, however the technical review will significantly delay evaluation of the IR.

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

SECTION 5.2 – REACTIVE POWER CAPABILITY OF THE DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is most readily available and can be recorded in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard. The Standard adopted "44%" as the injection capability for 0.90 pf, but the percentage is actually slightly less, 43.6%. Duke will consider capabilities 43.6% and higher also meet the intent of the 44% requirement. As a good practice, Duke recommends that all facilities be designed to operate at these pf ratings should the situation arise over the life of the facility that the facility would want this capability.

Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The reactive capability shall be provided on an inverter capability curve (P-Q graph) and shall be based at the rated voltage of the device (1 pu) and an ambient temperature of 35° C. The DER may choose to submit reactive capability data on a higher ambient temperature basis, however that data will still be applied as the 35° C capability (Duke cannot temperature adjust manufacturer data).

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[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

Because operating points on the chart can be difficult to accurately determine, it is recommended that the DER provide the numerical data that defines critical points on the capability curve. Those points include the Nameplate and Configuration apparent, active, and reactive power ratings at the leading, lagging, and unity power factors.

Some facilities have operational, design, or other limitations that prevent utilization of the full reactive capability of the device(s). If that is the case, the DER shall specify any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions). If no limitations are submitted, then Duke will consider that the facility has no reactive capability limitations. Duke recommends submittal of a facility capability curve that includes any limitations.

Supplemental Devices

If the DER includes supplemental devices, capability data must be provided for each device at rated voltage of the device and an ambient temperature of 35° C. Subject to the same conditions above, the DER may elect to submit data at a higher ambient temperature. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a brief written description and an acceptable power flow model of the device. If the supplemental device is static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

Again, any limitations that prevent the full reactive capability of the device(s) to be utilized shall be specified and Duke recommends submittal of a facility capability curve that includes the limitations.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

This section is ready to be implemented.

SECTION 5.3 – VOLTAGE AND REACTIVE POWER CONTROL

Listed below are the Standard voltage and reactive power control options and the default status for Duke interconnections:

Control Mode	Default Status
Constant power factor (fixed pf)	On, 1.0 pf
Constant reactive power (fixed VAR)	Off
Voltage-reactive power (Volt-VAR)	Off
Active power-reactive power (Watt-VAR)	Off

1

2 Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is
3 the broad category of control that includes unity power factor, which can be useful, but is limited by
4 operating at a control point that is not based on feeder conditions. Duke is in the process of performing
5 studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER.
6 The Duke study will evaluate the application and consequences of these functions.

7 Part of the study effort is to determine if voltage regulation functions should be activated and how they
8 should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the
9 system impacts, identify any unanticipated effects, and then assess the control modes and settings.
10 Because the impact of UDER reactive injection can be large, Duke limits the reactive capability that can be
11 used for reactive power control to 0.95 power factor.

12 In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed.
13 Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration
14 for residential-scale inverters as well. The reactive control method and settings should consider existing
15 operational requirements as well as mitigation of the high voltages that can occur with the addition of DER.
16 No change can be made on one part of the system that does not affect another part. Therefore, the study
17 will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts,
18 remediation of impacts, and controlling the impact on the transmission system. Distribution Providers
19 must comply with agreements and requirements of the transmission entities. As such, an evaluation of
20 transmission impacts is important.

21 Significant technical studies are required to evaluate these functions and analyze the consequences. The
22 studies began at the end of 2019 and will continue in 2021. This will continue to be an agenda item for the
23 TSRG meetings will focus on the most useful control modes and settings that are applied locally in the
24 inverter and are autonomous.

25 Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision.

26 Interoperability requirements: There will be few, if any, requirements for fixed power factor DER. For other
27 control modes, the interoperability requirements align with those in the EPRI document, Common File
28 Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020.
29 3002020201.

30 Verification and test requirements: To verify DER compliance to this requirement, Duke will require
31 evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage
32 tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may
33 be required to evaluate the DER's performance meeting this requirement.

34 Additional analysis must be performed before finalizing the Verification and test requirements.

35 Implementation of this section requires publishing the final position, applying the interoperability
36 functionality in the local interface, and integrating verification requirements into the overall commissioning
37 test program.

38

SECTION 5.4 – VOLTAGE AND ACTIVE POWER CONTROL

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: The interoperability requirements align with those in the EPRI document, Common File Format for Distributed Energy Resources Settings Exchange and Storage. EPRI, Palo Alto, CA: 2020. 3002020201.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

SECTION 6.2 – AREA EPS FAULTS AND OPEN PHASE CONDITIONS

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to

optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

SECTION 6.3 – AREA EPS RECLOSING COORDINATION

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

SECTION 6.4.1 – MANDATORY VOLTAGE TRIPPING REQUIREMENTS

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. As placeholders, the present trip setpoints are added to the Guidelines.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

For new DER installations, the present voltage tripping setpoints are provided in the table below.

Parameter	Voltage	Time
Undervoltage, UV Level 1	0.88 pu	10 cycles
Undervoltage, UV Level 2	0.5 pu	6 cycles
Overvoltage, OV Level 1	1.1 pu	10 cycles
Overvoltage, OV Level 2	1.2 pu	6 cycles

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.4.2 – VOLTAGE DISTURBANCE RIDE-THROUGH REQUIREMENTS

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

See Section 1.4 for the abnormal performance category.

1 Interoperability requirements: To be determined.

2 It is expected that these values will be set and not changed remotely, however this position must be
3 evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be
4 a beneficial capability. Because requirements are not known at this time, Duke must perform additional
5 analysis before establishing interoperability requirements. Note that this setting is incorporated in
6 SUNSPEC MODBUS.

7 Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-
8 through settings and field setting verification. Due to complication of performing abnormal voltage tests in
9 the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating
10 conformance of the DER, and currently does not plan to require field commissioning tests on this topic.
11 Operational data collection after a DER or system event may be required to validate proper DER operation.
12 IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for
13 this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip
14 function is required.

15 Implementation of this section requires publishing the final position and applying the interoperability
16 functionality in the local interface.

17 6.4.2.6 Dynamic voltage support

18 At least one Duke region requires dynamic reactive compensation for transmission connected DER.
19 Application for the distribution system is still under evaluation.

20

SECTION 6.5.1 – MANDATORY FREQUENCY TRIPPING REQUIREMENTS

21
22

23 Duke Energy has not determined the guidelines for this section, but these requirements are being
24 developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements. As placeholders, the
25 present trip setpoints are added to the Guidelines.

26 For new DER installations, the present frequency tripping setpoints are provided in the table below.

Parameter	Frequency	Time
Underfrequency, UF	57 Hz	10 cycles
Overfrequency, OF	60.8 Hz	10 cycles

27

28 Interoperability requirements: To be determined.

29 It is expected that these values will be set and not changed remotely, however this position must be
30 evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be

a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

SECTION 6.5.2 – FREQUENCY DISTURBANCE RIDE-THROUGH REQUIREMENTS

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)
UL certification testing should verify the inverter will ride through a 3 Hz/s excursion in accordance with abnormal operating performance Category III. That being the case, no generator on the utility system shall intentionally trip for ROCOF using protective relaying or DER controller functions. DER tripping for ROCOF, if available, should be off or disabled. The DER shall certify that protective relay settings & controller settings do not intentionally trip for ROCOF.

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through
The UL 1741 SB certification shall be considered sufficient for individual inverter based DER devices meeting ride through requirements for this function. The DER shall certify that protective relay settings & controller settings of the completed DER facility do not intentionally trip for the voltage phase angle changes specified by the Standard.

1 This function, either at the inverter or the utility PCC recloser, is still under evaluation as part of an ongoing
2 project involving the Protection and Transmission Planning groups. Duke anticipates adopting the
3 requirements above if that is supported by the ongoing project.

4 6.5.2.7 Frequency-droop (frequency-power) capability

5 Duke accepts the default operation conditions and settings in the Standard as written:

Operation for low-frequency conditions	Mandatory
Operation for high-frequency conditions	Mandatory

6

Parameter	Setting
dbOF, dbUF (Hz)	0.036
kOF, kUF	0.05
T-response (small-signal) (s)	5

7
8 At this time, a frequency deadband of 36 mHz and a droop of 5% are considered acceptable for inverter and
9 non-inverter sources. As the mix of generation sources transition over time, it may be necessary to
10 transition to a lower values in the future to maintain EPS reliability.

11

12 This function is still under evaluation as part of an ongoing project involving the Protection and
13 Transmission Planning groups. Per Standard table 24, a specification of the droop, deadband, and
14 associated parameters is required for Category II and III.

15 6.5.2.8 Inertial response

16 Duke Energy has not determined the guidelines for this subsection. This capability is not required by the
17 Standard but is permitted.

18 Interoperability requirements: To be determined.

19 It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this
20 position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the
21 setting would be a beneficial capability. Because requirements are not known at this time, Duke must
22 perform additional analysis before establishing interoperability requirements. Note that this setting is
23 incorporated in SUNSPEC MODBUS.

24 Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-
25 through settings and field setting verification. Due to complication of performing abnormal frequency tests
26 in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of
27 evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this
28 topic. Operational data collection after a DER or system event may be required to validate proper DER
29 operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the
30 provision for this method. Adjustment of the shall-trip settings may be made if verification of the
31 mandatory trip function is required. Also note for the individual functions, that Duke reserves the right to
32 verify that protective relay settings & controller settings do not interfere with or prevent proper
33 performance the various ride-through requirements.

1. Implementation of this section requires publishing the final position and applying the interoperability
2. functionality in the local interface.

3.

SECTION 7.2.2 – RAPID VOLTAGE CHANGES

5. Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage
6. Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is
7. consistent with the Standard and does not plan further evaluation.

8. Interoperability requirements: To be determined.

9. Based on the type of inrush mitigation used, there could be some status points that are useful for
10. situational awareness. Because requirements are not known at this time, Duke must perform additional
11. analysis before establishing interoperability requirements.

12. Verification and test requirements: The installation evaluation is currently included in the scope of Duke's
13. interconnection inspection process, but the performance of the inrush mitigation is not currently tested. A
14. power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and
15. mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-
16. energize test).Duke will develop a test procedure and criteria to evaluate the performance of a RVC
17. mitigation solution as part of the commissioning tests.

18. Implementation of this section requires applying the interoperability functionality in the local interface and
19. integrating verification requirements into the overall commissioning test program.

20.

SECTION 7.2.3 – FLICKER

22. Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453
23. recommended practices.

24. Interoperability requirements: No specific requirements for this section.

25. Verification and test requirements: Duke plans to review design document and equipment specification to
26. evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to
27. follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or
28. system event may be required to validate proper DER operation.

29. This section is ready to be implemented.

30.

SECTION 7.3 – LIMITATION OF CURRENT DISTORTION

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section. Installation of a power quality meter is already part of the required design for DER 1 MW and greater.

Verification and test requirements: Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.1 – LIMITATION OF OVERVOLTAGE OVER ONE FUNDAMENTAL FREQUENCY PERIOD

Duke Energy adopts these requirements as written in the Standard.

Part of 7.4.1 is based on the inverter design and operation and part is based on the specific design of the interconnection and the Area EPS itself. The ability of the inverter to detect and limit overvoltage will be verified by UL certification testing. However, the DER facility must still be analyzed during system impact study to verify the impact of the combined inverter and Area EPS is below the limits of the Standard. The limits defined in parts a) and b) must be verified by power system study.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to rely on UL certification testing, review type tests results, and examine design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

SECTION 7.4.2 – LIMITATION OF CUMULATIVE INSTANTANEOUS OVERVOLTAGE

Duke Energy has not determined the guidelines for this section. More industry experience or analysis could be essential to address this issue. Duke does not plan to implement this section until IEEE 1547.1 is revised

and UL 1741 certification tests include this verification. At that time, Duke expects to adopt these requirements as written in the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position.

SECTION 8.1 – UNINTENTIONAL ISLANDING

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories. As placeholders, the expected requirement is noted below.

Duke accepts the requirements in the following Standard sections as written:
      8.1.1 General
      8.1.2 Conditional extended clearing time
      8.1.3 Area EPS with automatic reclosing

The standard clearing time for an unintentional island is 2 seconds. The DER shall identify and provide the method of islanding detection* used for all DERs above 250 kW.

Interoperability requirements: No control points are expected. Need to determine if any monitoring is necessary.

Verification and test requirements: Duke plans adopt the unintentional islanding test procedure in IEEE 1547.1-2020. For a DER that has autonomous capabilities to detect unintentional islands, the cease-to-energize function test as defined in the existing inspection and commissioning process shall be used to verify compliance.

* Such as one of the six groups listed in section 2.3 Generic Island Detection Groups and Response Models of Inverter-Onboard Islanding Detection Assessment: Final Project Report. EPRI, Palo Alto, CA:2020. 3002014051.

SECTION 10.3, 10.4 – NAMEPLATE AND CONFIGURATION INFORMATION

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
  - The rating is the most capacity the system is designed to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
  - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.
- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

1 UNADDRESSED REQUIREMENTS OF IEEE 1547-2018

2 The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the

3 completion of the higher priority topics. Concerning the clauses and sections not addressed in this

4 document, Duke Energy expects that the DER shall conform to the Standard itself as written.

5

6

1 APPENDIX – IEEE 1547-2018 BENCHMARKING

2 Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January
3 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant
4 Consulting, Inc.

5 TABLE B.1. BENCHMARKING OF IEEE 1547-2018 FUNCTIONALITIES IMPLEMENTATION

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

1

DER Commissioning Update

Kevin Chen   7/21/2021

DUKE ENERGY

- Self-inspection Update

- End of 2021 Commissioning Process Update

- Transmission Connected IBR Inspection and Commissioning

- Q&A, open discussion

Attachment F

- All previously developed self-inspection documents are posted on the TSRG website.

- The self-inspection technical training was on 2/11/2021. The link to the video and presentation slides is posted on the TSRG website.

- Duke is working on the self-inspection pilot project and would like to have more volunteers.

- Duke believes we need to have a process or program applied to the Generating Facilities, at which Duke has not performed inspections or commissioning tests, per NCIP Sections 6.5.2 and 6.5.3.

  - To minimize the safety and reliability risk in MV construction quality or site maintenance

  - To ensure consistency between actual installation and Duke approved equipment

  - To collect and periodically update the interconnection devices settings for compliance verification and future study need

- Duke will continue to engage with stakeholders to develop and improve the process.

Attachment F

- Self-inspection Update

- End of 2021 Commissioning Process Update

- Transmission Connected IBR Inspection and Commissioning

- Q&A, open discussion

Attachment F

- Duke and AE anticipate total of 52 distribution-connected sites (>1MW) to be commissioned before 12/31/2021. (16 completed, 3 active, 33 projected)

- The _DER Construction Reference Guide July 2021 version_ is released.

- Links to the 2019 and 2020 training videos and presentation slides are posted on the TSRG website. Duke does not plan to produce new materials for full training in 2021.

- Duke listened to the comments and feedback from customers about the high cost and long duration of the inspection and commissioning of some projects. We understand customer's need for overall lower cost and quicker turnaround.

- Duke worked with AE to simplify the scope of inspection and streamline the commissioning process without compromising the established standards and requirements in the Interconnection Agreement and Interconnection Procedure.

  1) Duke and AE are reaching out to each customer to schedule 1-on-1 mini session to help customers understand the commissioning process and answer any technical questions about construction standards or good utility practice.

     - Already talked to 3 developers.

     - Will continue this with other customers that have projects coming in 2021.

Attachment F

2) Reduced scope of inspection by dropping the inspection of low voltage AC side of the facility. The scope of inspection now includes electrical equipment from the secondary side of the MV transformers to the point of interconnection.

3) Some less significant MV construction issues will no longer be "required corrections". These issues will be verbally communicated with customer representative(s) during the onsite visit and will be briefly documented in the inspection report.

4) Updated the commissioning test scope to include confirming and verifying the expected performance in the commissioning test. This should help both customer and AE with a clear passing criterion in determining test results.

❖ These process updates and scope changes should help the customers, who have no major construction quality issues in their projects, on the cost and length of the commissioning process.

▪ The updated _Duke Energy PV Interconnection Commissioning_ process document will be released soon.

▪ The _2021 End-of-Year PV Commissioning Guidelines_ (conditional PTO process) document is under revision and will be released as soon as practicable.

Attachment F

- Self-inspection Update

- End of 2021 Commissioning Process Update

- Transmission Connected IBR Inspection and Commissioning

- Q&A, open discussion

Attachment F

- Duke Energy transmission planning and operation have been closely following the NERC reliability guidelines and the development of IEEE P2800 about the interconnection requirements for Inverter-Based Resources (IBR) connected to transmission system.

- Duke is developing an inspection and commissioning process for transmission-connected IBR facilities to ensure the facilities meet the interconnection reliability requirements.

- Duke hired AE to visit several transmission-connected solar facilities to explore how the new process may look like. The preliminary scope of site visit activities includes:

  1) Verify the installed equipment matches the approved equipment and SLD

  2) Verify the Power Plant Controller (PPC), circuit breakers, inverter settings

  ❖ The MV construction quality inspection is NOT currently in the scope.

- Once Duke has drafted a process, it will be presented to and reviewed by the TSRG.

Attachment F

- Self-inspection Update

- End of 2021 Commissioning Process Update

- Transmission Connected IBR Inspection and Commissioning

- Q&A, open discussion

TSRG Meeting July 21, 2021

Distributed Energy Technology (DET)

Operations Role

Introduction – Darren Maness

- Engineering & Business Background
- 30 years work experience

- 19 years - Duke Energy & Progress Energy
  - Audit Services – Energy Delivery
  - Energy Delivery – Business Services
  - Supply Chain – Inventory Optimization, Combined Cycle Warehouses, Category Mgmt.
  - Distributed Energy Technology – Transitioned into Operations role May 2021

- 11 years – Prior
  - Automotive Product Development
  - Manufacturing Engineering
  - Process Improvement Consulting – Lean Six Sigma

2

DET Operations Role

DET is working to implement Queue Reform in the Carolinas & support interconnections processes

Interconnection Studies	Interconnection Construction	**Technical Standards** • Inspection & Commissioning • Technical Polices • Operations	Strategy & Planning	Data Systems & Business Controls

Operations Need

- Focus on Ongoing Operations to support increasing number of developer owned solar facilities

- Outage coordination (planned and unplanned)

- Coordination of post COD activities and operations reporting

- Single point contact and liaison for operations related issues

- Improve customer satisfaction with increased coordination, communications, and transparency

3

DET Operations Role

Operations Reporting

- 2020 - Pilot report developed. Pulls data from DataMart, SCADA, and PI Vision
- Today – Weekly Open Reclosers Report. Sent to Customer Delivery senior management & teams
- Future - Expand to include equipment failures, outage duration & frequency, reliability, etc…

Outage Communication

- July 1 - Launched new e-mail address DEROperations@duke-energy.com

Outage Coordination

- Interface between solar customers and Customer Delivery organization

4
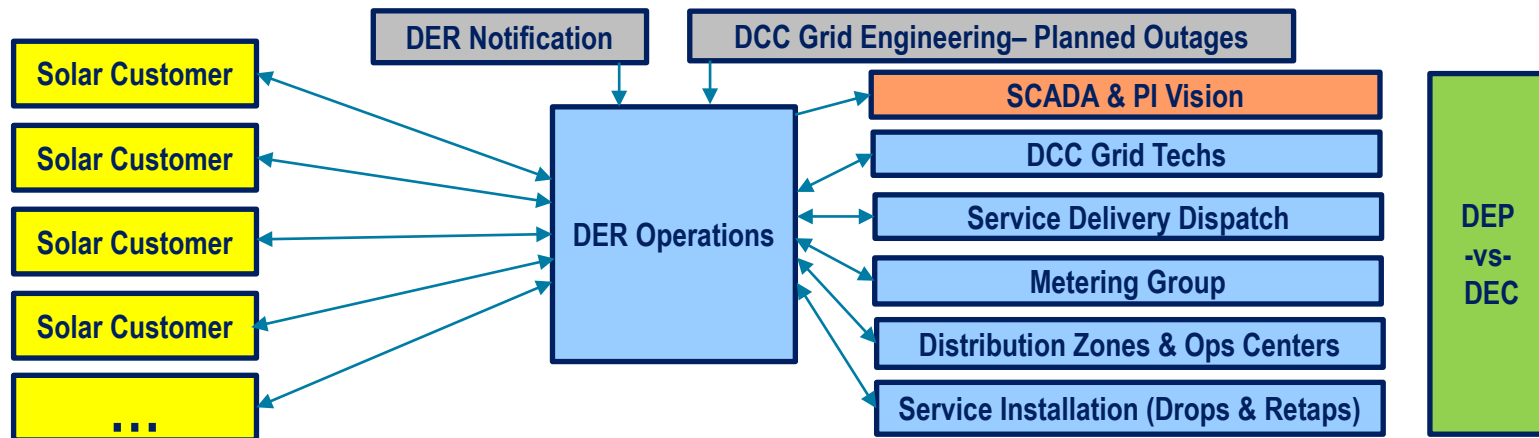
Initial Tracking (May 1 – July 16)

- 100 customer contacts established
- Operations log: 159 requests or issues
  - Includes 82 DER Notifications (planned & unplanned outages)
- Can start looking at the data. For example:

Qty	Request or Notification
54	Recloser Checks
32	Duke Planned Outages (Switching, Software, PQ Meter, FCB, Mobile Sub)
15	Customer Inspect Facilities (No Issues Found)
13	Customer Planned Outages
7	Duke Metering Pole PT/CT/Cluster
6	Hot Spots (Duke)
6	Blown PT or CT
5	Blown Arrestors
4	Battery Alarm
2	Burned Jumpers
2	Fires
1	Load Encroachment
1	Loose Jumper
1	UG Cable Failure
1	Reclose Fault
1	Cleared Fuse
1	Car Wreck
1	Fallen Tree

- Focus is on Continuous Improvement - process steps, handoffs, efficiency, etc…

- Expand Outage Reporting
    - Operations Analysis – trending, drivers, restoration lead times, bottlenecks
    - Develop reportable metrics
    - Inventory staging opportunities at ops centers

- Continue providing updates to the TSRG group

TSRG   **Operations**